DEEP FOUNDATION CONSTRUCTION CHALLENGES AT THE NEW BENICIA-MARTINEZ BRIDGE

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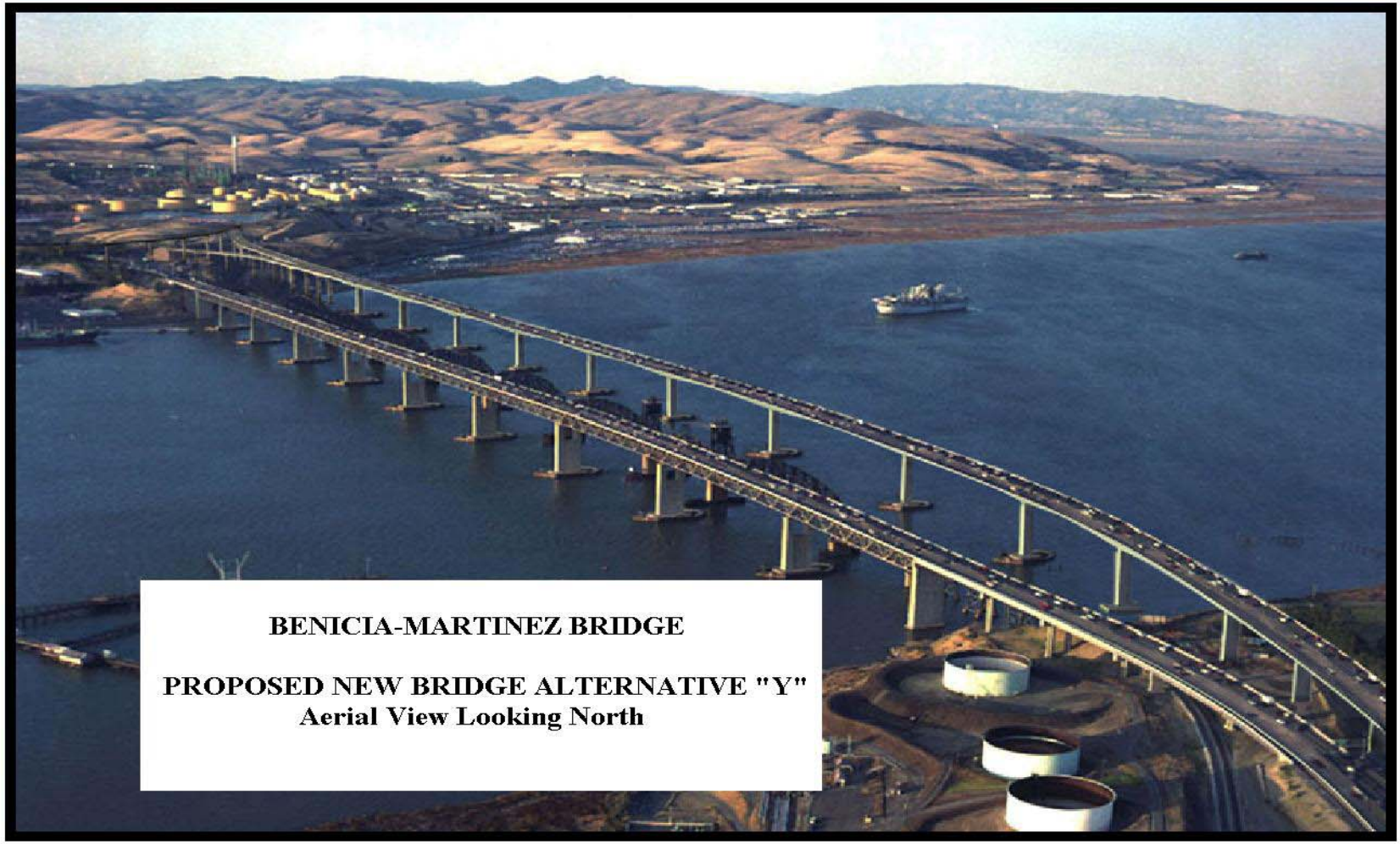
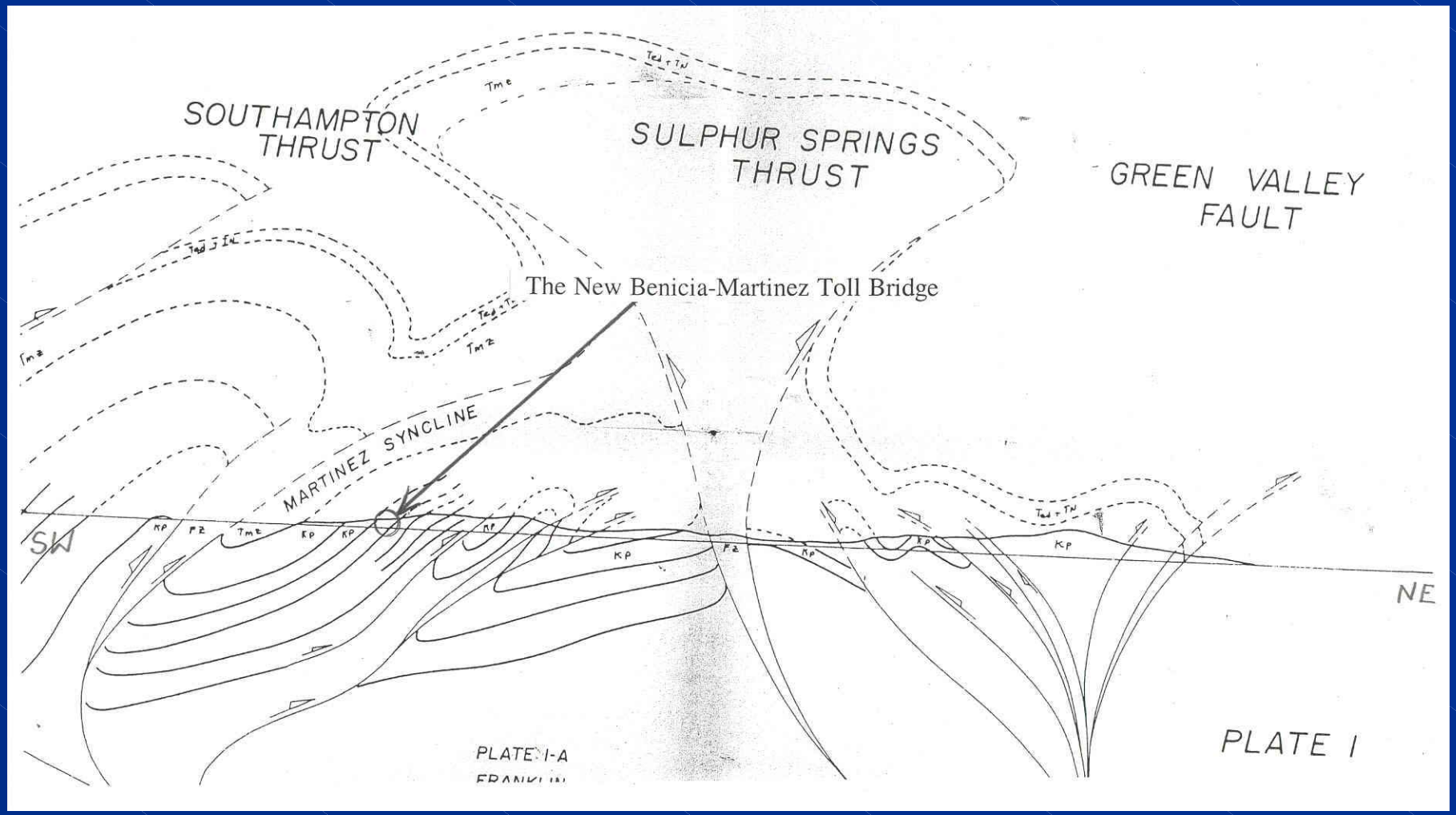
New Benicia-Martinez Bridge - Alternative “Y”



Geology


SOUTHAMPTON THRUST
SULPHUR SPRINGS THRUST
GREEN VALLEY FAULT
The New Benicia-Martinez Toll Bridge
MARTINEZ SYNCLINE
SW
NE
PLATE I-A
PLATE I

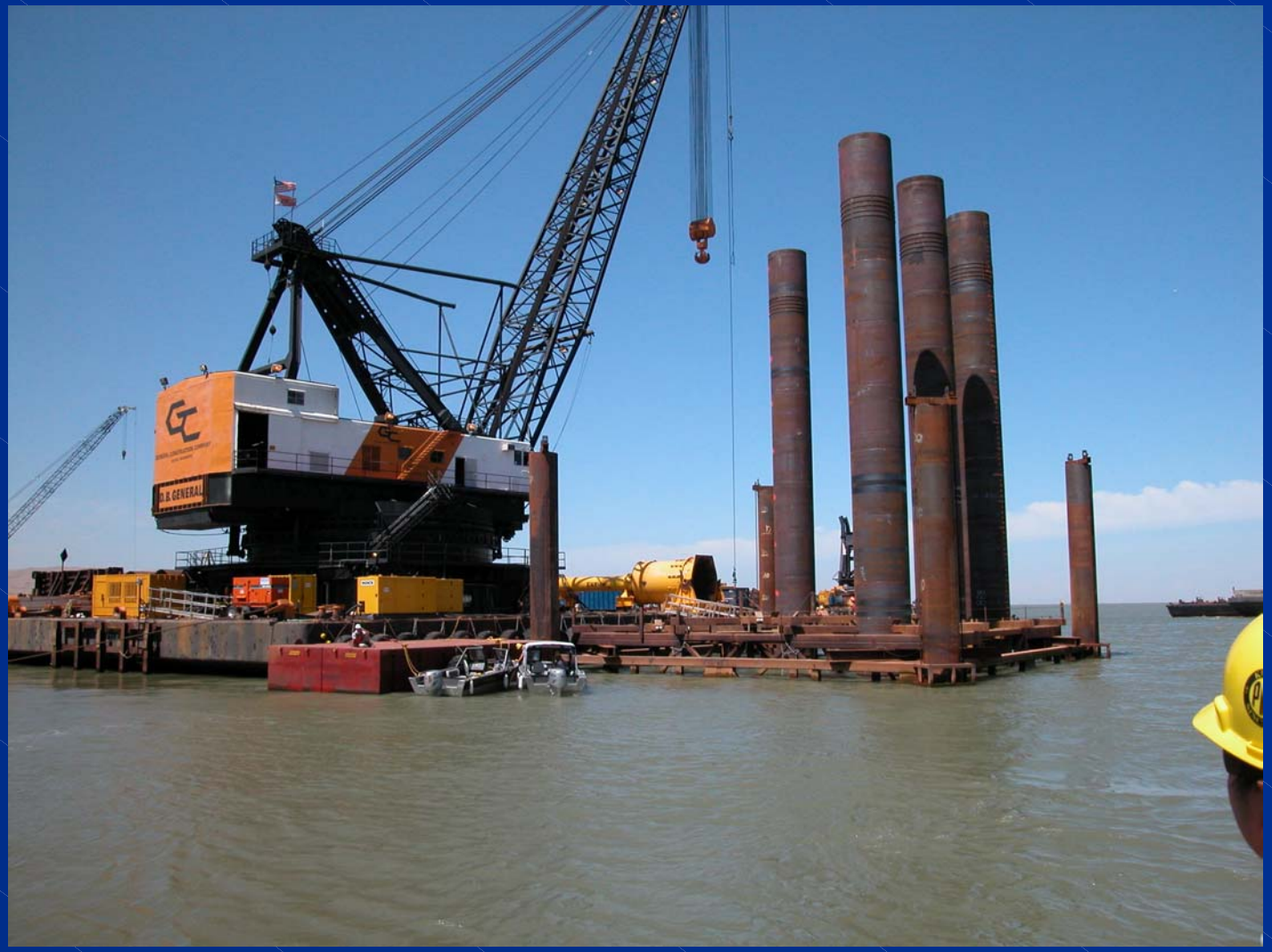
Pier Foundation

- 99 marine CIDH piles up to 78 m long
- 2.5 m dia. permanent steel casing with 2.2 m dia. rock socket
- Permanent casing to be installed 2 to 15 m into bedrock to meet lateral demand
- Nominal resistance demand per pile up to 66 MN in compression and up to 57 MN in tension

Three Major Construction Challenges

- Fish protection
- Pile driving into bedrock
- Caving during drilling of rock socket

Driving 2.5 m Diameter Steel Casing



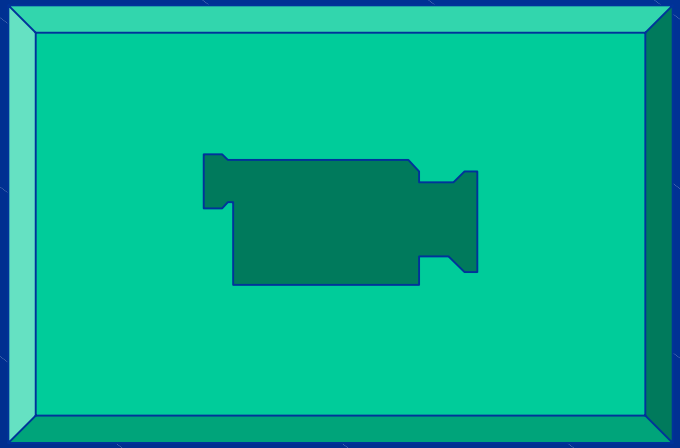
FISH Challenges Our Bridge Foundation!

Pile Driving and Environmental Monitoring

Impact to fish species:

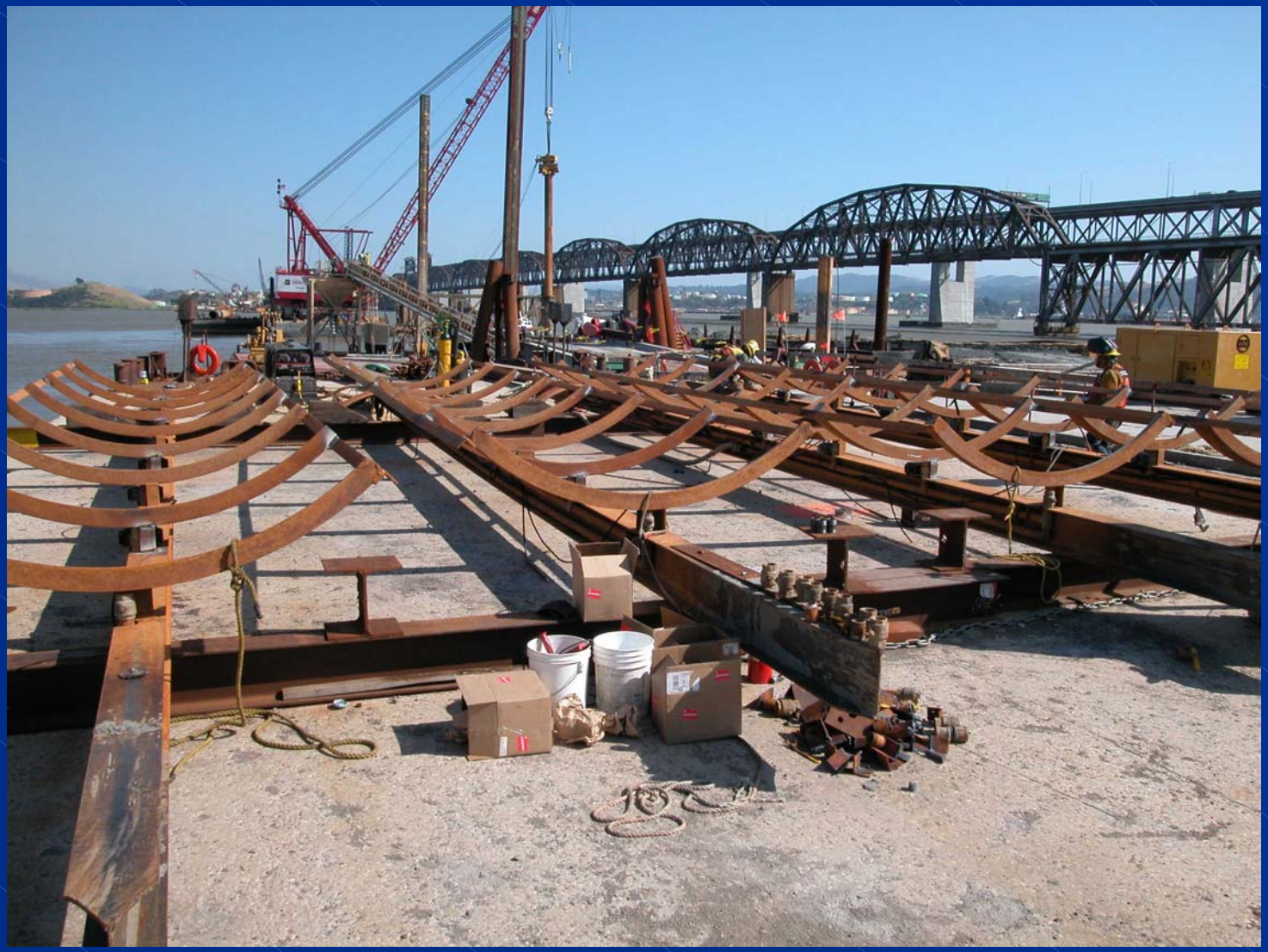
- < 150 dB : no impact
- 150 - 180 dB : harassment (no lethal)
- 180 - 204 dB : delayed mortality
- > 204 dB : lethal

Pile Driving with “Bubble Curtains” (Video)



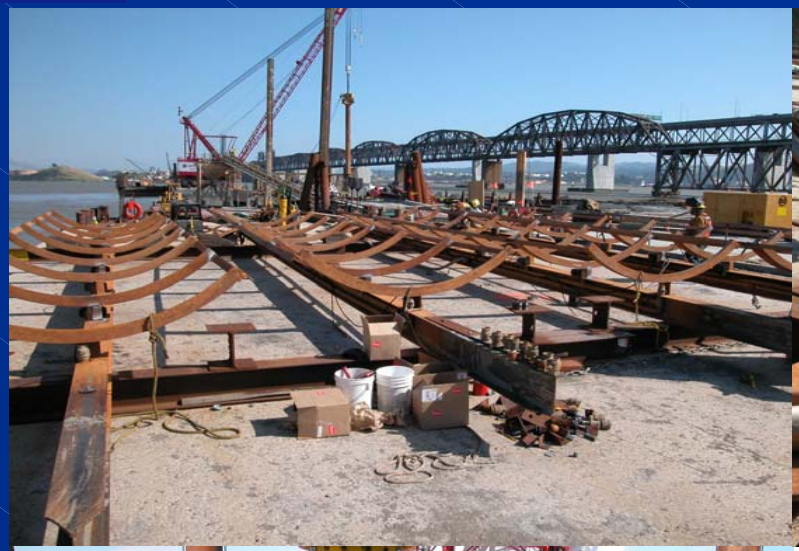
Pile Driving in Shallow Water

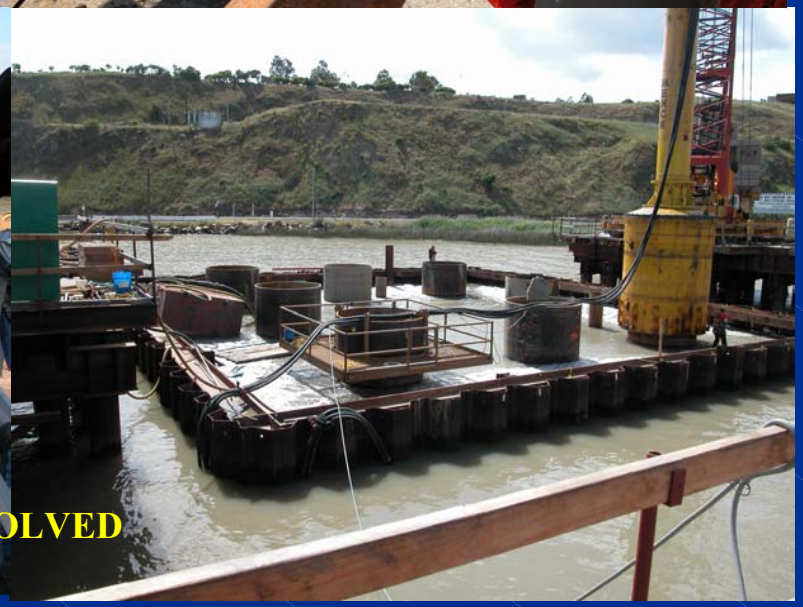
Bubble Curtains Used at New Benicia-Martinez Bridge



Small Holes on the “Bubble Tree”

Bubble Curtains Used at New Benicia-Martinez Bridge





FISH PROTECTION ISSUES WERE RESOLVED AFTER 9 MONTHS DELAY!!!

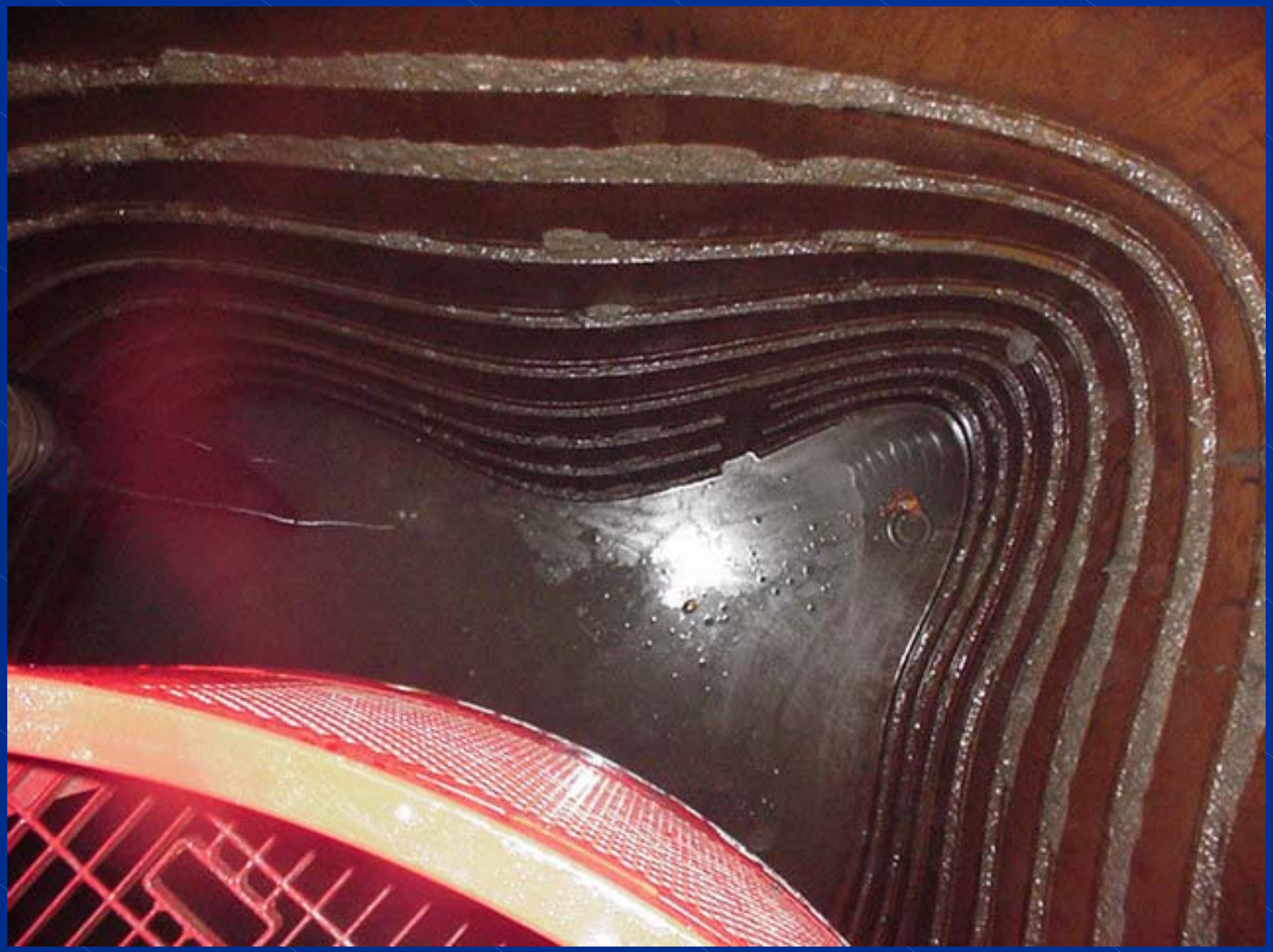
Driving Steel Casing into Bedrock

- Menck MHU-500 hydraulic hammer rated energy: 550 kJ
- Steel casing wall thickness: 41 mm
- Driving shoe: 0.45 m long and 61 mm thick
- Rock penetration: 2-15 m with center-relief-drilling
- RQD: 0-100%; qu: 2,700 - 53,000 kPa
- PDA monitoring required
- End of driving blow counts: 550/0.3 m
- Peak max. stress: 240 MPa (70% of steel yield strength)

Steel Casing Damages

Steel Casing Deformed to Oval Shape

Lower Portion of the Casing Squeezed



Cone Shaped Bottom Half-Cut

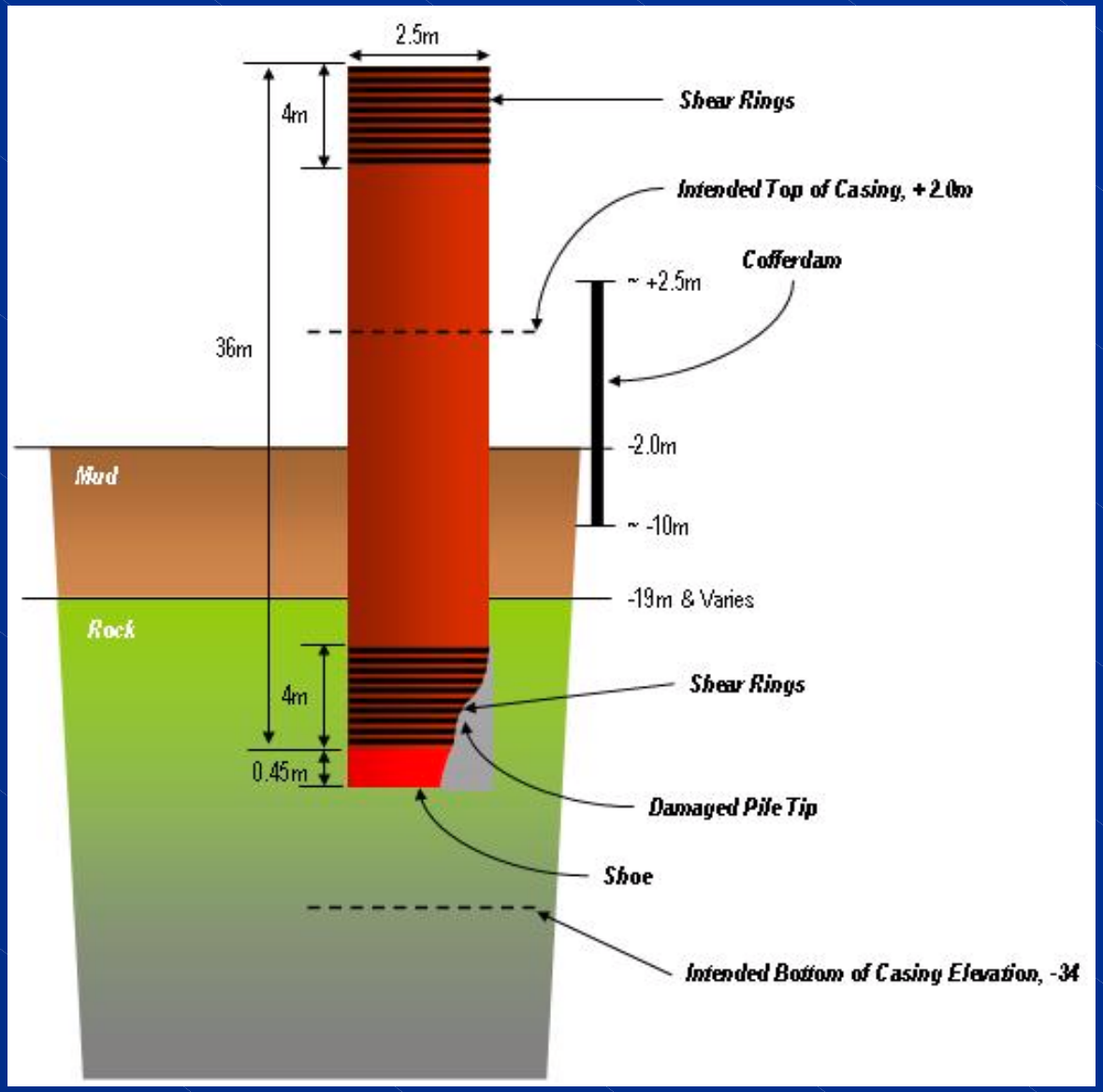
Deformed Piece Cut and Retrieved

Folded Piece Cut and Retrieved

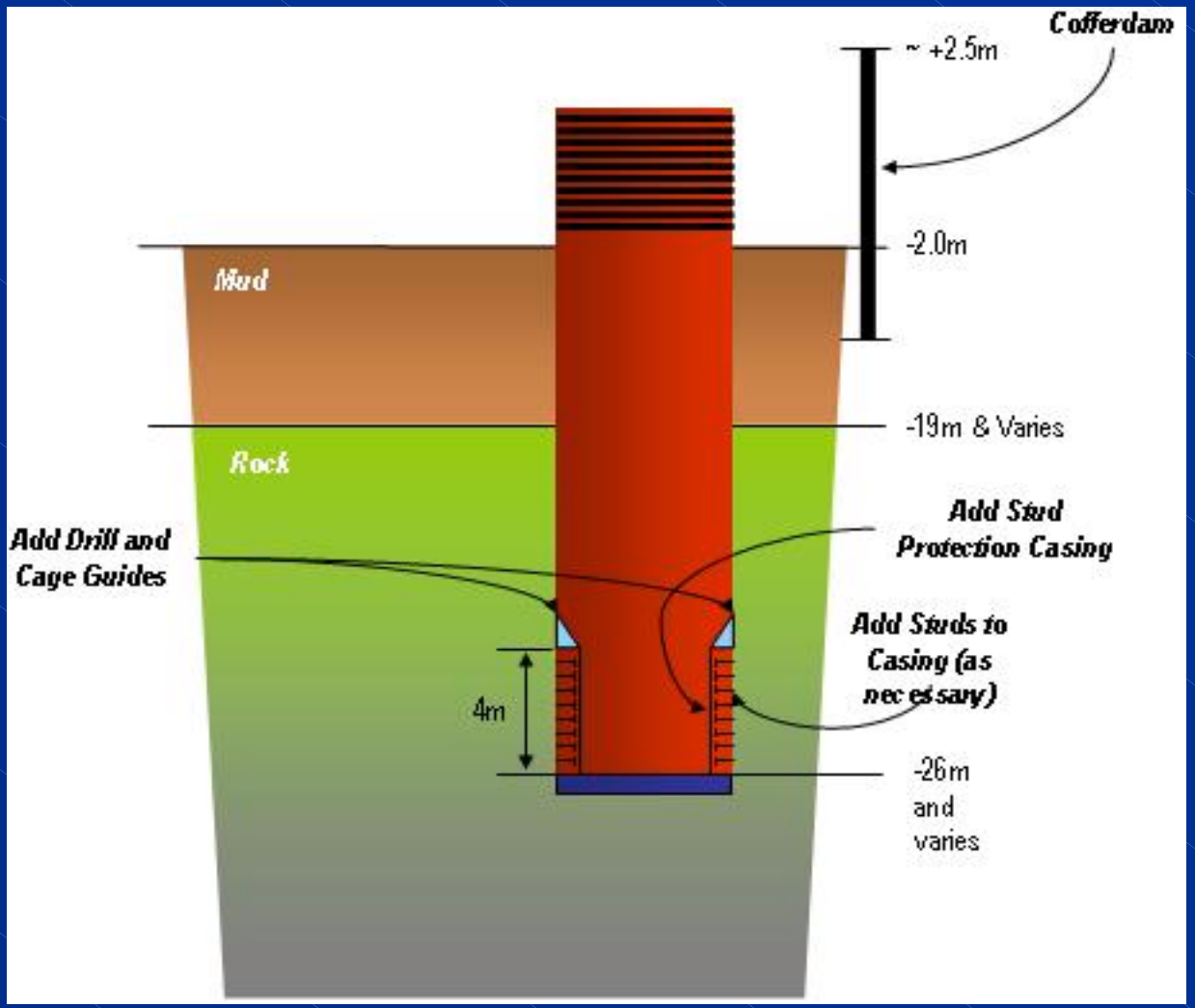
Recommendations and Remediation

- Limit driving to 200 blows per 0.3 m
- Mandatory center-relief drilling
- Modification to design for damaged casings

Casing Repair Scheme (Before Repair)



Casing Repair Scheme (After Repair)



Are All Problems Solved?

-FISH PROTECTION ISSUES WERE RESOLVED

-PILE DRIVING ISSUES WERE RESOLVED

Drag Bit Used for Existing Bridge (Did NOT Work)

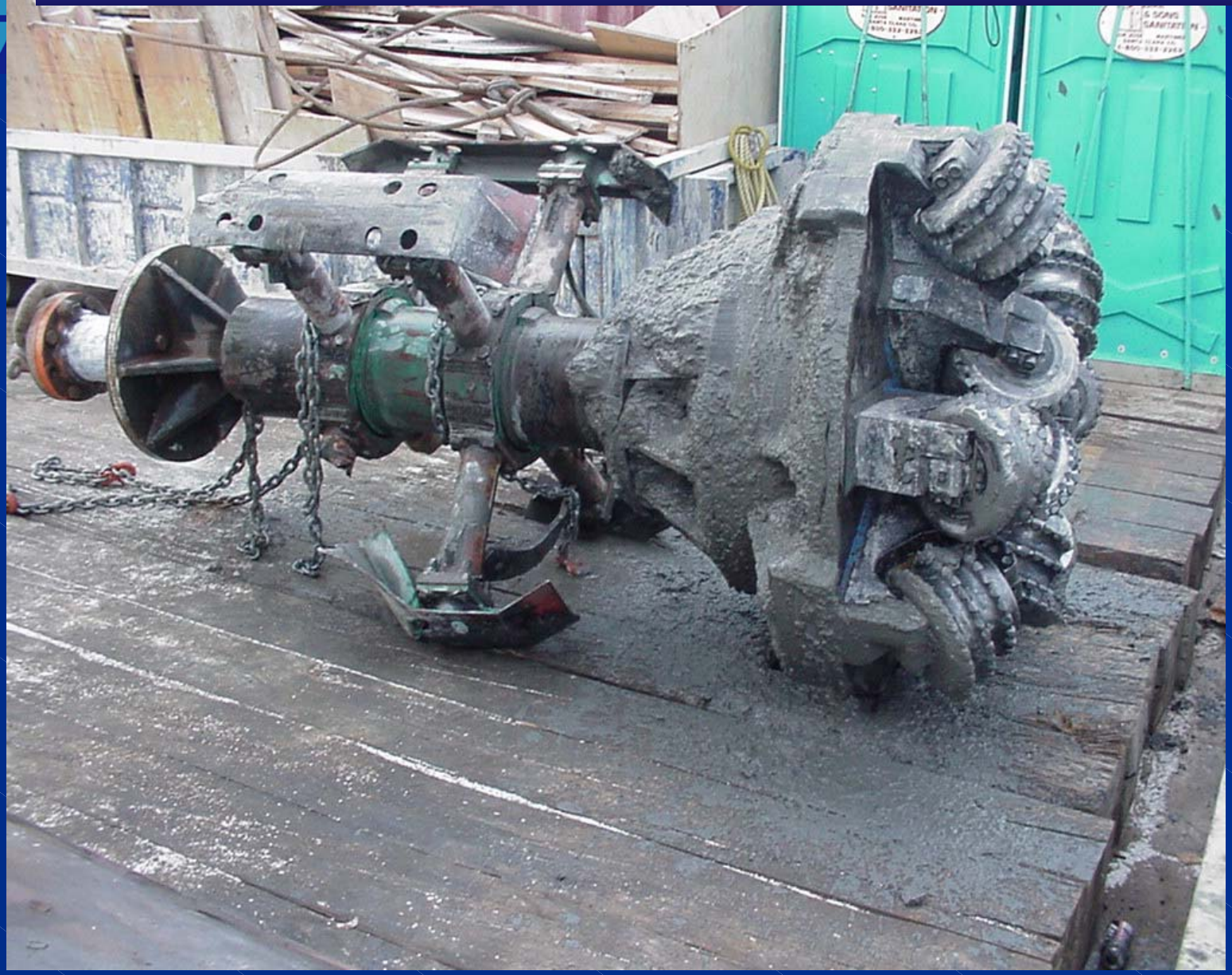
Drill Rod Used for Existing Bridge

Roller Bit Used for Existing Bridge (DID Work)

Roller Bit Drill System Used for Existing Bridge

Roller Bit Drill Used at the Benicia-Martinez Retrofit

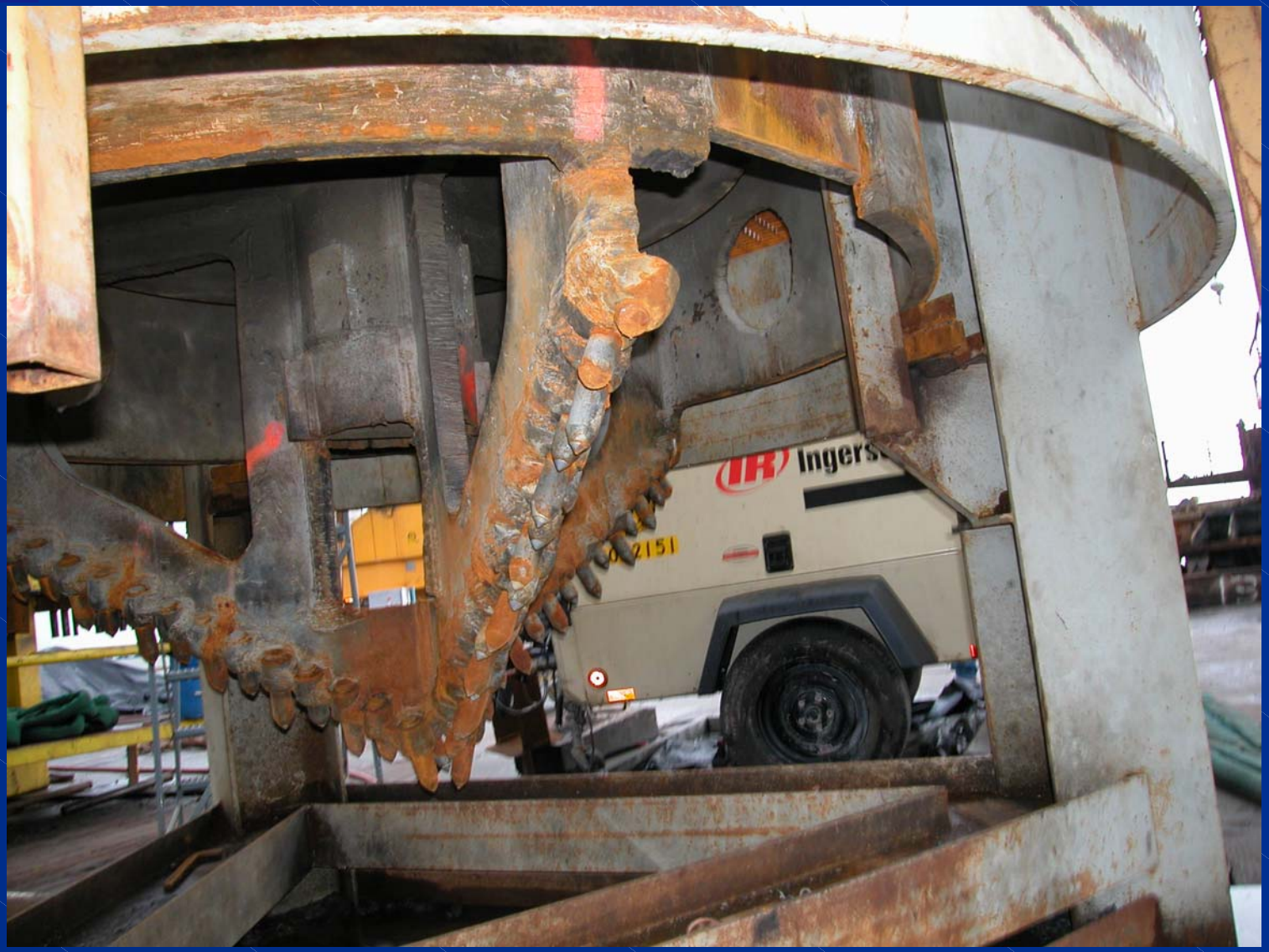
Roller Bit Used at the Benicia-Martinez Retrofit



Over-Reaming/Roller Bit Used at New Carquinez Bridge

Drilling System Used at the New Benicia-Martinez Bridge

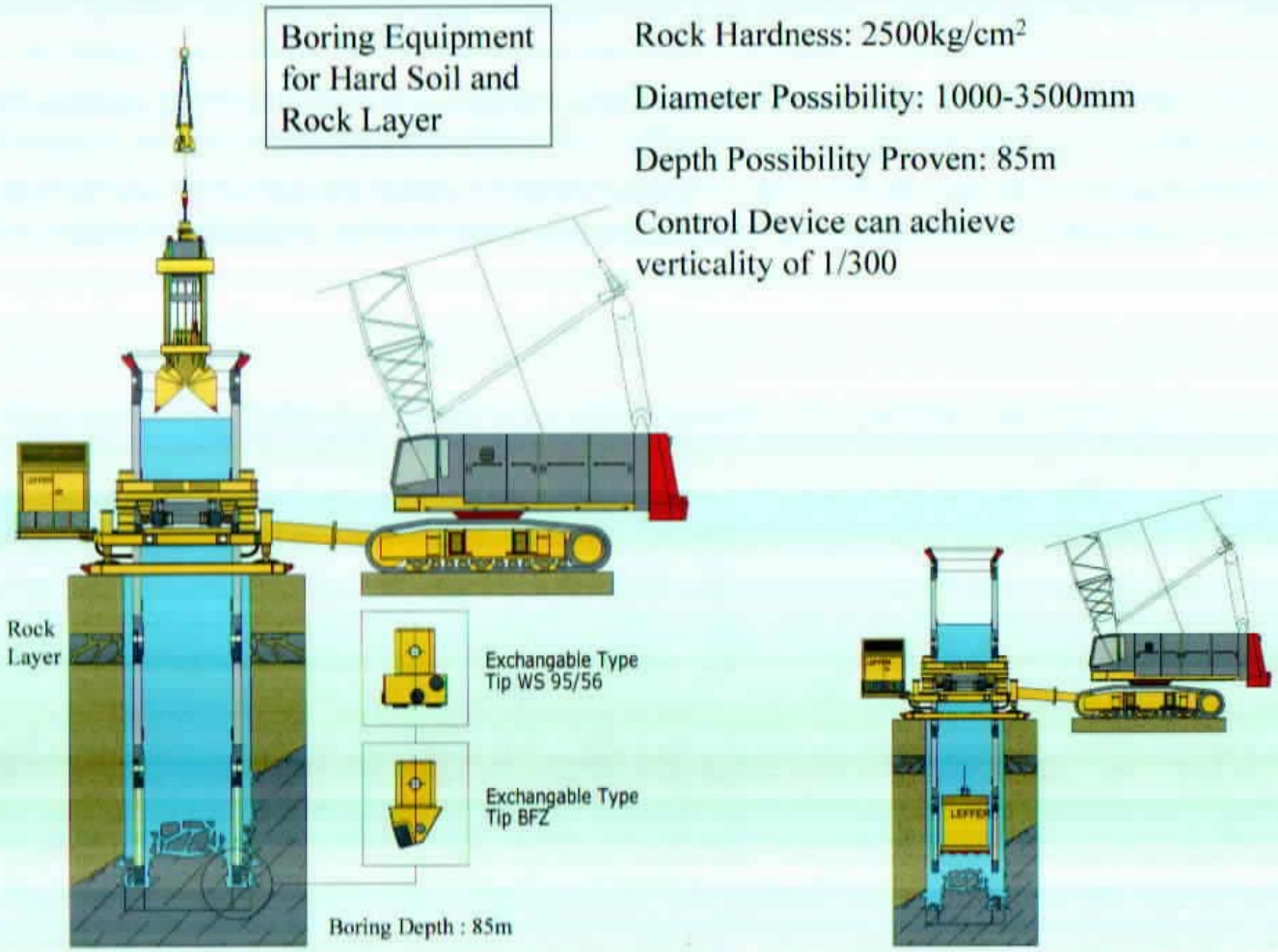
Modified Drag Bit Selected by the Contractor



Drilling Bucket Used at New Benicia-Martinez Bridge

Rotator Casing Construction Method

Rotator Equipment Setup



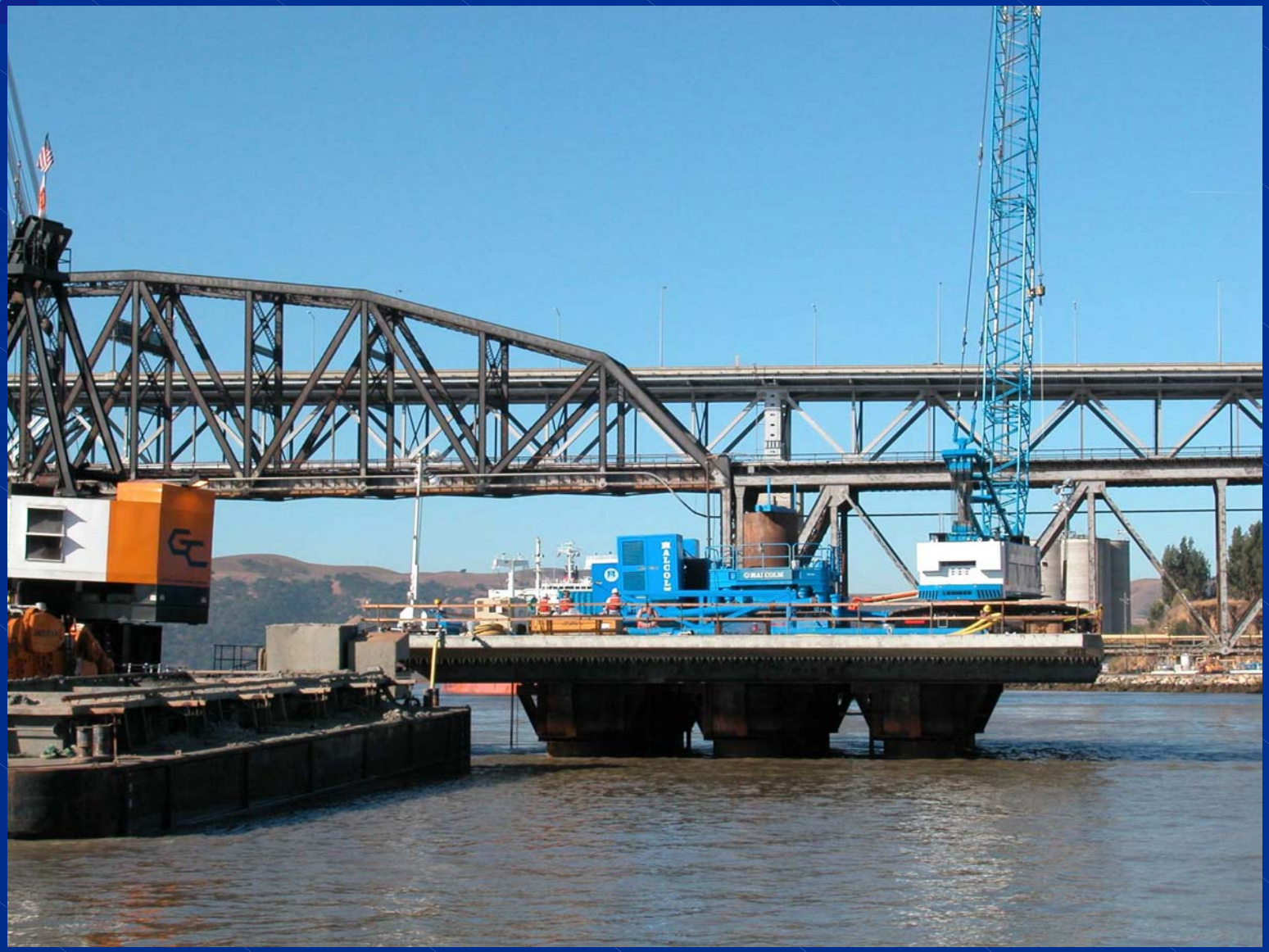
Rotator

Challenges:

- Never used offshore (torque resistance)
- Requirement for self-standing rebar cages
- Smooth shaft with possiblely reduced skin friction

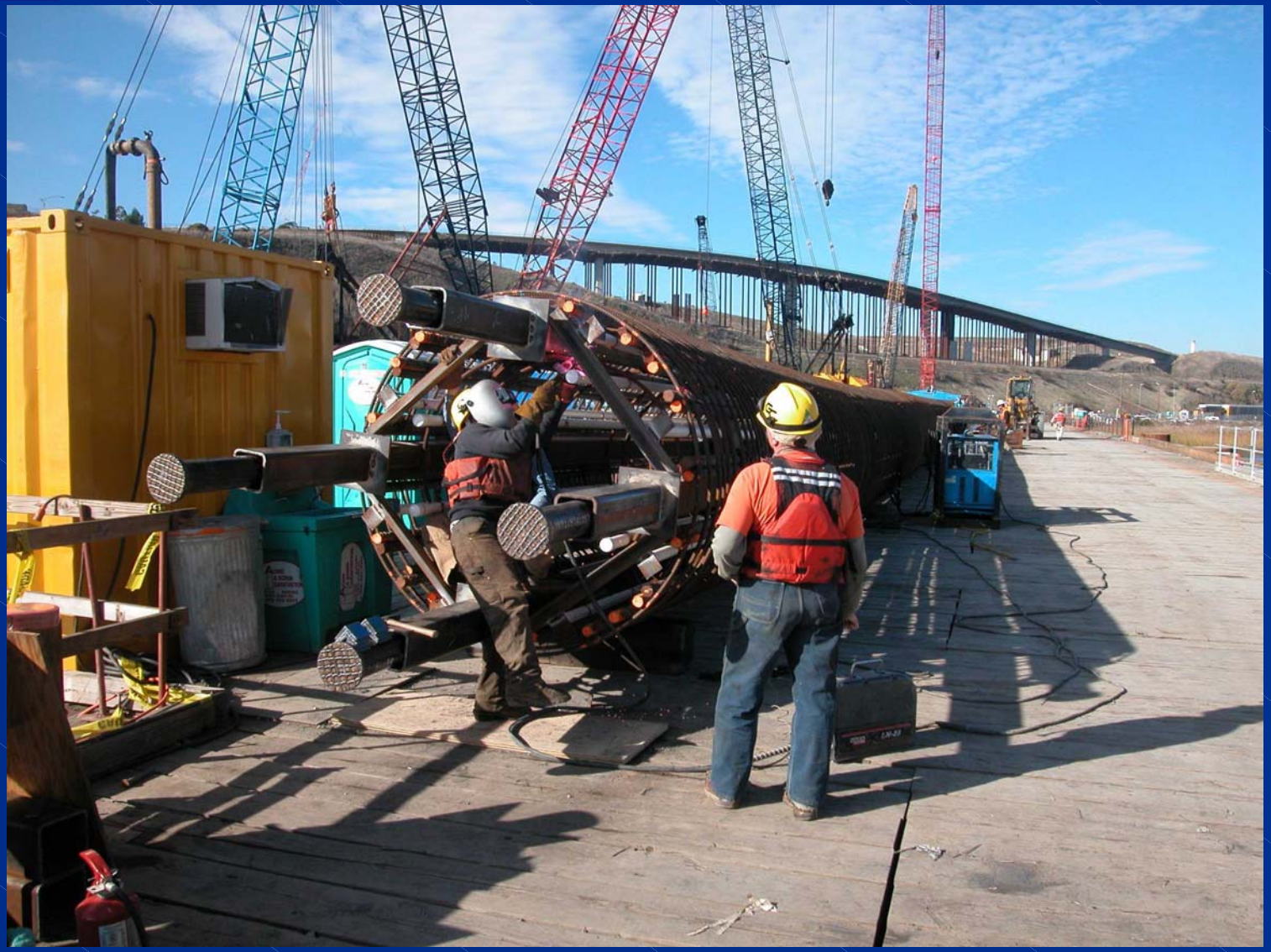
Custom-made Steel Attachments for the Rotator Platform

Rotator on the Drilling Platform



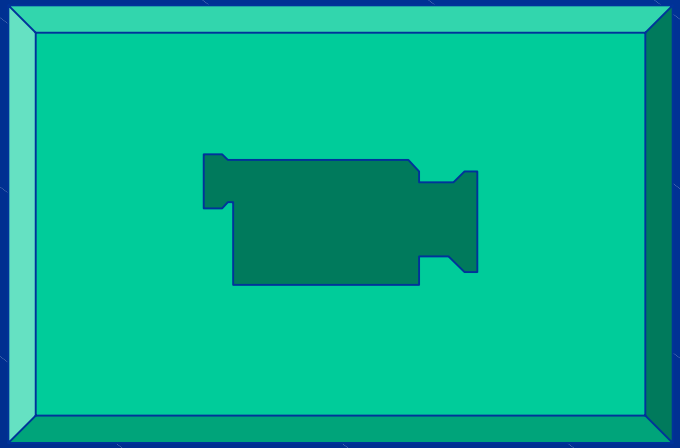
Hammer Grab Removing Rock Cuttings

Self-Standing Rebar Cage with Hydraulic Legs

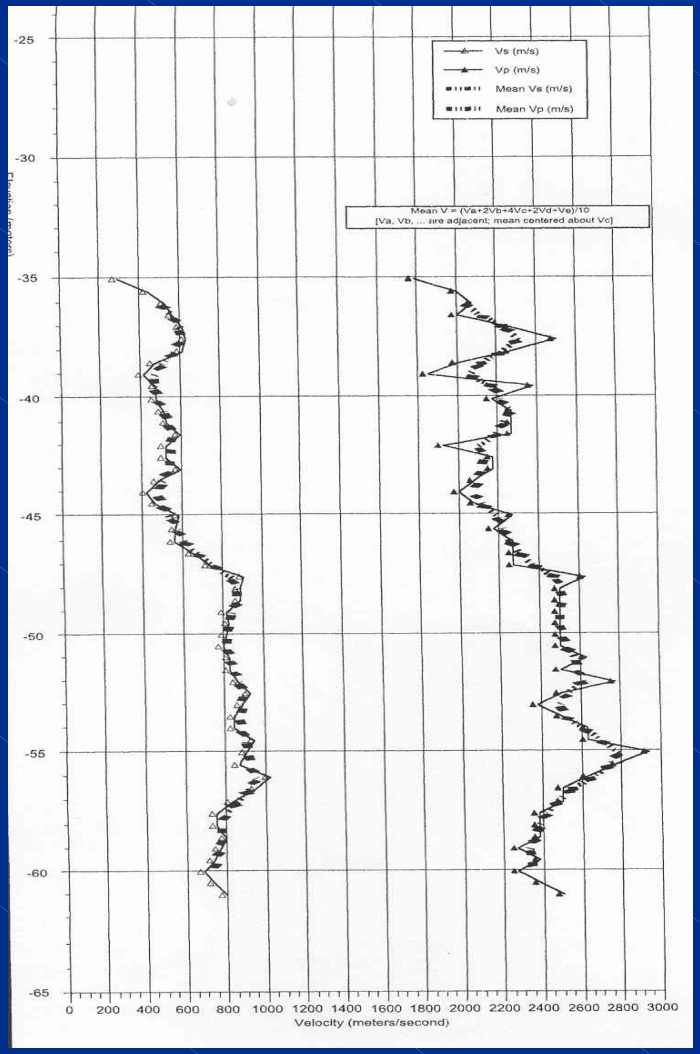


Rotator Casing with Teeth at Bottom

Roughness from Conventional Drilling (Video)



Pile Load Test



- Pier 14 - representative of both weak and moderately to hard rock
- Osterberg method -1 test only

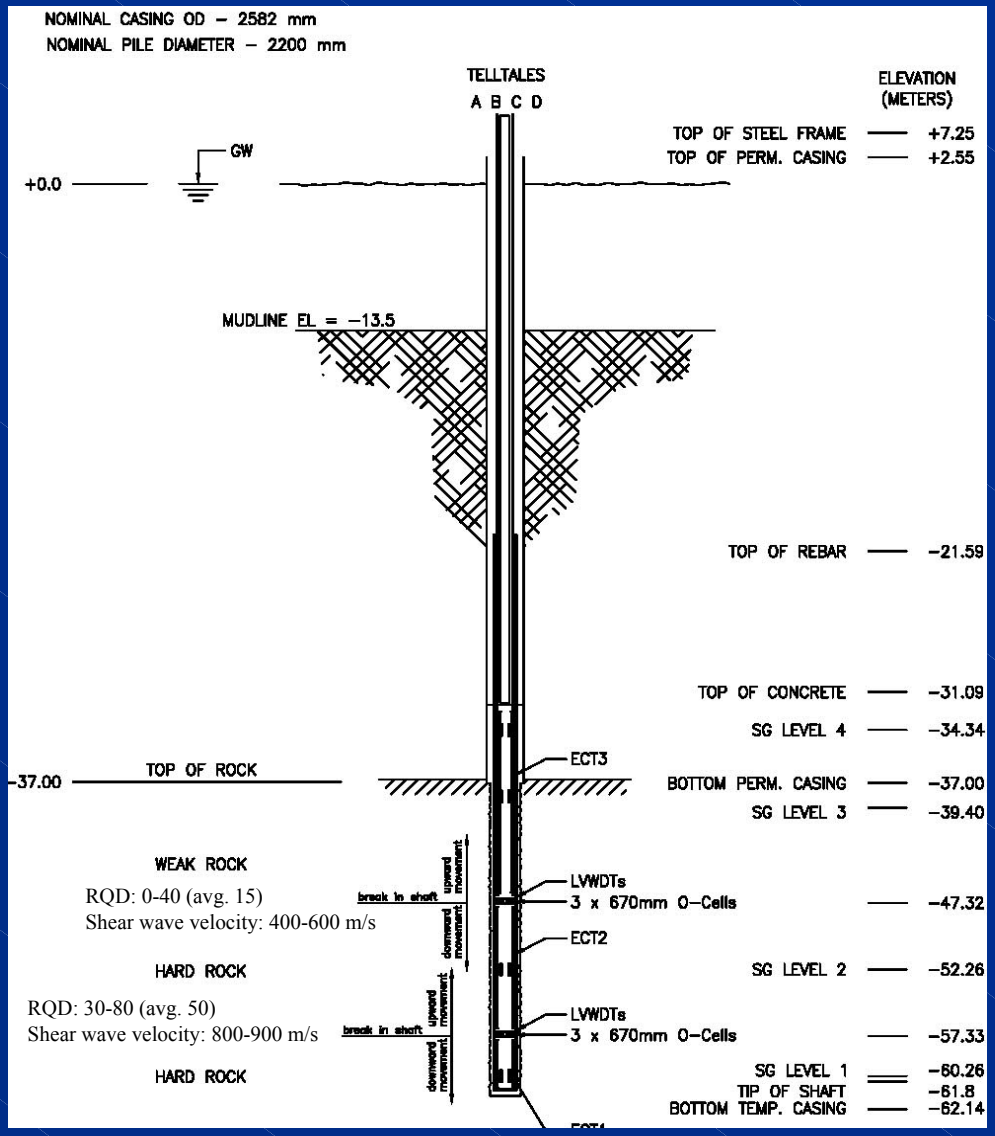
Weak rock:

- RQD: 0 to 40 (average of about 15)
- Shear wave velocity: 400 to 600 m/s

Hard rock:

- RQD: 30 to 80 (average of about 50)
- Shear wave velocity: 800 to 900 m/s

Schematic Sections of Load Test Shaft



Ultimate pile capacity up to 66 MN or 7400 Tons:

- casing friction
- side shear from weak rock
- side shear from hard rock
- end bearing capacity

Multi-level multi-stage test:
2 levels:

- 3 670 mm O-cells at each level
- 75 mm compressible material at bottom of the cage

4 stages:

- Stage 1: lower harder rock
- Stage 2: upper 10 m weak rock and steel casing
- Stage 3: end bearing
- Stage 4: residual side shear

Testing capacity: up to 100 MN or 11,240 Tons (50 MN in each direction)

670-mm Osterberg Load Cell

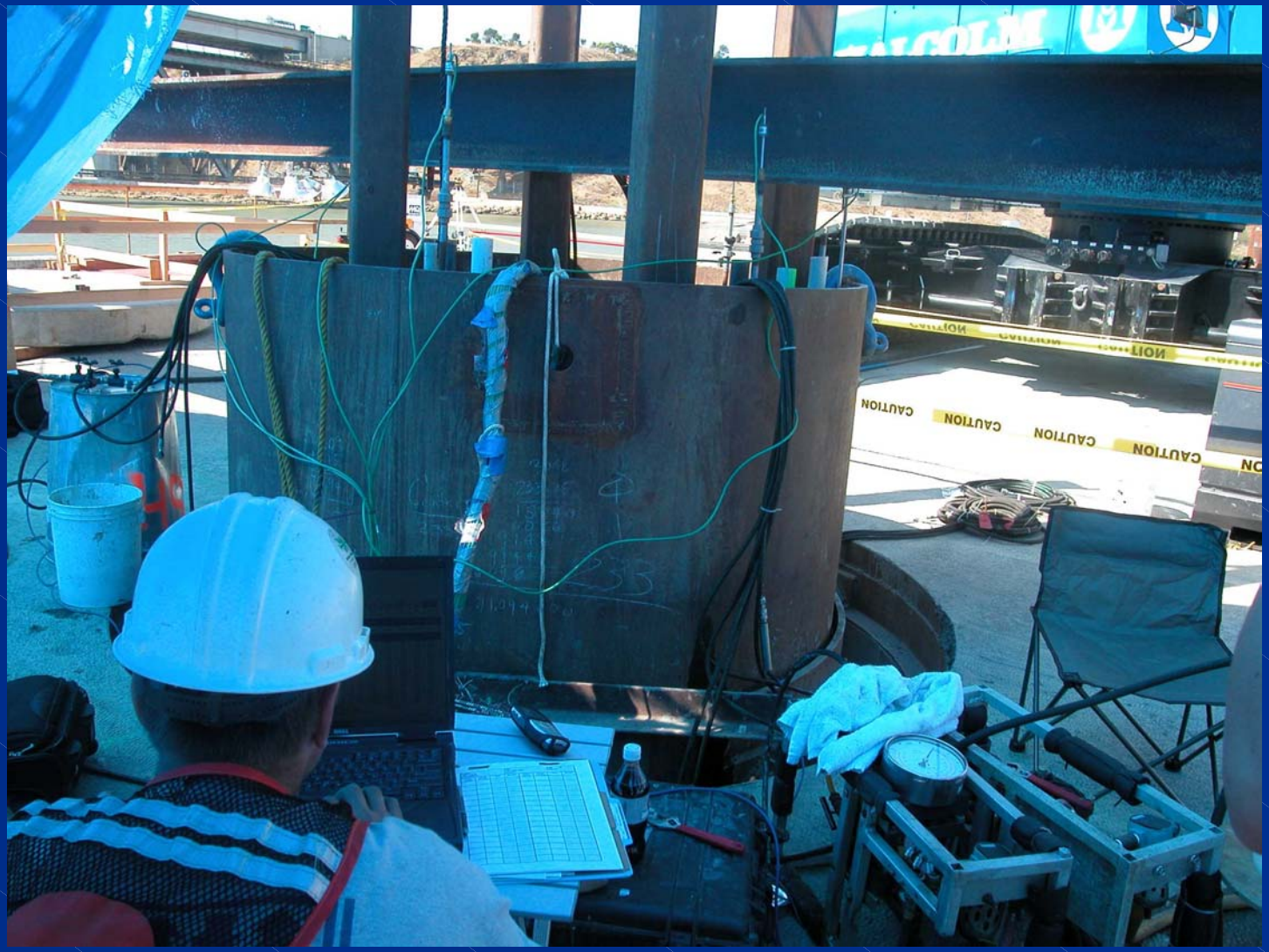
O-Cell Load Test Cage and Wiring

3-inch Thick Compressible Bottom Device

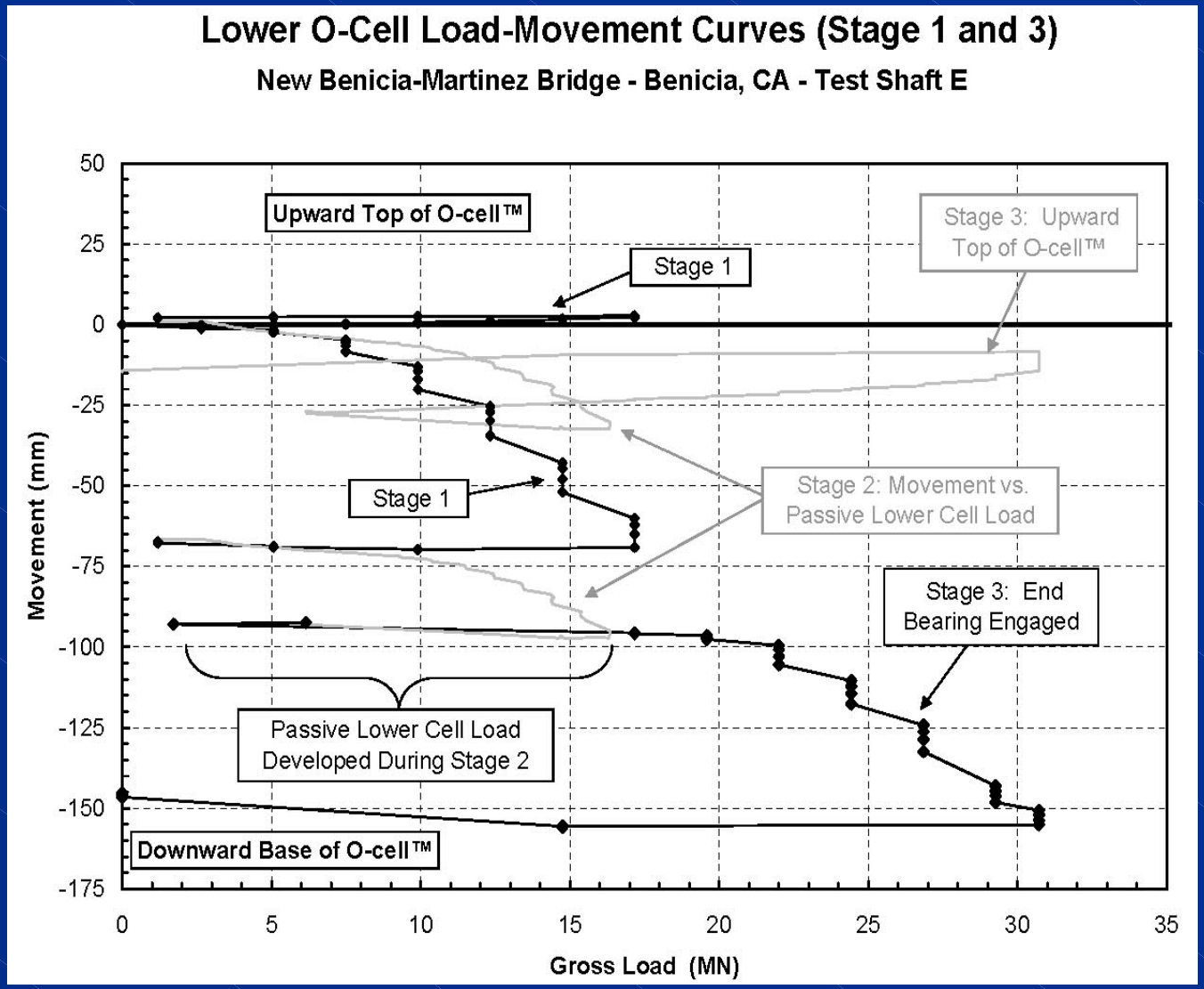
O-Cell Load Test Setup

O-Cell Load Testing

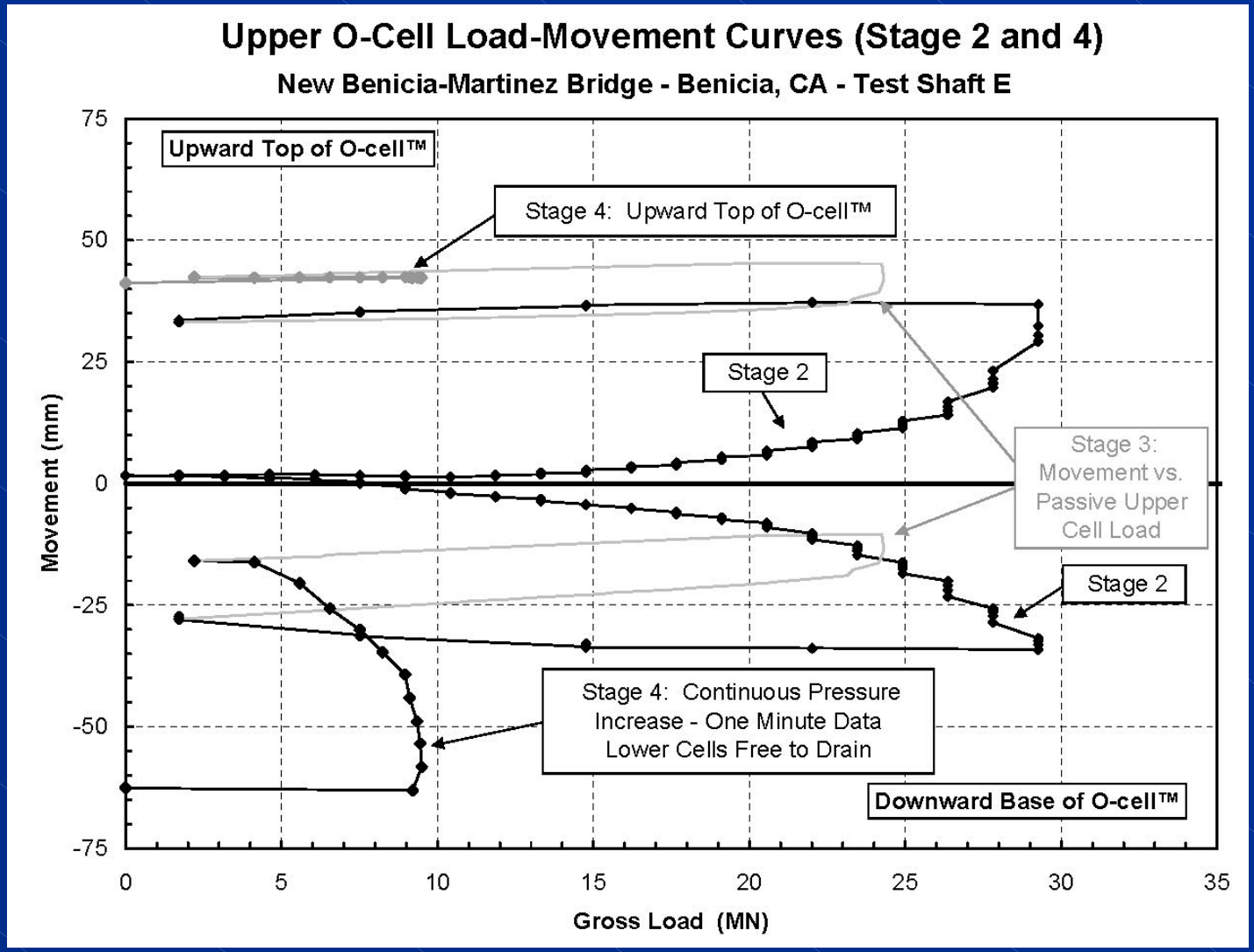
Pile Load Test in Progress



Pile Load Test - Stage 1 and 3



Pile Load Test - Stage 2 and 4



Pile Load Test Findings

- The test results ***surprisingly*** indicate that side shear for both low RQD intensely weathered rock and higher RQD slightly weathered to fresh competent rock are about the same at approximately 280 kPa.
- The end bearing pressure at the bottom of the rock socket is approximately 4.5 MPa at a displacement of about 75 mm.

Shaft Inspection Device (Mini-SID)

Mini-SID Shaft Bottom Inspection

Conclusions

- The bubble tree curtain system without attenuating casing was proved to be effective in protecting fish.
- Pile driving in bedrock may be problematic. To avoid damage, a longer driving shoe and/or center-relief-drilling with a diameter close to or larger than the steel casing (over-reaming) should be considered.
- Pile load testing is very critical in confirming the static design of rotator drilled shafts in bedrock, especially when harder rock actually doesn't provide larger side shear as we expected.

Pier 9 Column